



# Glacier Bay National Park and Preserve Oceanographic Monitoring Program *2011 Annual Report*

Natural Resource Technical Report NPS/SEAN/NRTR—2013/729



**ON THE COVER**

Margerie (left) and Grand Pacific (right) glaciers enter the head of Tarr Inlet. Glacial inputs of cold, fresh, sediment-laden water profoundly influence the oceanography of Glacier Bay.

NPS photo

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# **Glacier Bay National Park and Preserve Oceanographic Monitoring Program**

## *2011 Annual Report*

Natural Resource Technical Report NPS/SEAN/NRTR—2013/729

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## Abstract

The Southeast Alaska Inventory and Monitoring Network (SEAN) assumed responsibility from the USGS for long-term oceanographic monitoring of Glacier Bay in 2009. 2011 is the 19<sup>th</sup> consecutive year of the continuous dataset, and this is the third annual report. As operational conditions allowed, vertical profiles of temperature, salinity, light, turbidity, dissolved oxygen concentration, and chlorophyll fluorescence were obtained for the water column once in late winter and once in mid-summer at 22 permanent stations throughout Glacier Bay (although cast data from the winter cruise were ultimately disqualified due to equipment failure); seven of those stations were occupied monthly from March through October, and an eighth was formally added in August. In general, parameters reflected typical ranges and spatial (both horizontal and vertical) and temporal trends expected for a high-latitude tidewater glacial fjord, with strong seasonal signals and strong length-of-fjord gradients along the glacier-to-baymouth transects. The water column was well-mixed in winter and strongly stratified in summer. Fluorescence measurements indicated phytoplankton production occurred in surface waters from late spring through fall, presumably fueled by a near-continuous injection of nutrients to the euphotic zone by tidal, wind, and/or internal wave induced mechanisms. Compared to historical data, a relatively cold, salty, and dense water column anomaly below 10-m depth was observed during July in the central bay. The third consecutive year of significant departures from the historical mean, 2011 closely resembled 2009, while 2010 was anomalously warm, fresh, and low-density. These observations highlight Glacier Bay's inherent variability on inter-annual timescales. The 2011 sampling year marked the first with a dedicated survey vessel and the initiation of a three-year ocean acidification study that involves water sampling from discrete depths through the water column. Analyses of these samples (results reported elsewhere) will significantly enhance our understanding of Glacier Bay oceanography

## Acknowledgments

For assistance with 2011 field data collection I thank S. Reisdorph, T. Bruno, J. Latendresse, Chris Sergeant, B. Moynahan, S. Danielson, W. Bredow, J. Mathis, N. Monacci, R. Sharman, B. McDonough, R. Thomas, G. Coraggio, M. Hazen, E. Sharman, M. Slovin, J. Fisk, and S. Timm. Oceanographic data can be collected only when there are vessels and operators available to deploy instruments at stations. The 2011 data were collected during nine cruises that were logistically supported by the Glacier Bay National Park and Preserve (GLBA) Resource Management, Visitor and Resource Protection, and Maintenance Divisions; special thanks to the Visitor and Resource Protection Division (use of the vessel Talus in September) and vessel operators T. Bruno, J. Latendresse, and W. Bredow (Visitor and Resource Protection Division), C. Sergeant (SEAN), and B. McDonough (Maintenance Division). In particular, T. Bruno and J. Latendresse conducted the entire March cruise alone, and C. Sergeant operated the Fog Lark for a portion of the mid-summer July cruise when I was unavailable. Additionally, I thank the GLBA Maintenance Division, particularly B. McDonough, for ongoing vessel maintenance. Special thanks to W. Johnson for developing routines that automate some data analyses and visualizations, and to C. Sergeant for some data summaries. Reviews by S. Danielson and L. Etherington resulted in substantial improvements to this report.

## Introduction

Oceanography is one of several long-term monitoring “vital signs” identified by the National Park Service (NPS) Southeast Alaska Inventory and Monitoring Network (SEAN) as important in order to be able to continually assess the ecological health of Glacier Bay National Park and Preserve (GLBA; Moynahan et al. 2008). A detailed oceanographic monitoring protocol (Danielson et al. 2010) was developed to standardize data collection, analyses, and reporting. This 2011 annual data report documents the third year of data collection following the development of that protocol. Annual reports summarize the field efforts and resulting data of the previous sampling year. The “oceanographic sampling year” begins with a mid-winter cruise in December or January and ends with an October cruise, after which the measurement instrument receives annual service and sensor calibration. Calibration results allow for final data to be certified, and the annual report is typically generated in January or February. The annual report is intended to be a timely release of summarized data, and it includes a narrative description of field activities, unusual or otherwise noteworthy observations, and graphical and tabular data summaries to place the data in historical context. It is succinct and synoptic in nature, and is aimed at a primary audience of GLBA managers, researchers, and interested stakeholders from the public at large. Care has been taken to assure accuracy of raw data values upon which this report is based; a more analytical interpretation of the data is undertaken in a more comprehensive but less frequent trend report (typically issued on a regular five-year basis). The first of these long-term data analyses covers 1993-2009 (Danielson 2012).

Long-term monitoring of Glacier Bay oceanographic parameters is a key element of informed park management. Glacier Bay’s ocean waters strongly influence ecosystems across the entire GLBA. Together with weather, bathymetry, and glaciers and other terrestrial influences, oceanographic components determine horizontal water movement and vertical stability, thereby driving the spatial and temporal dynamics of energy, and physical, chemical, and biological characteristics of the water column. Marine biological communities and their constituent components—from primary producers to apex predators—are fundamentally controlled in this way. Moreover, because the land/ocean interface is porous to the transfer of energy, materials, and biophysical signals, the Glacier Bay marine system is an important physical and biological driver of adjacent terrestrial systems. Consequently, for park managers to fully understand and protect all park resources, they must start with the waters of Glacier Bay itself. In addition to having a basic knowledge of oceanographic components and processes, it is essential to monitor key parameters that are likely to influence the condition of many specific resources—both marine and terrestrial—throughout the park and region.

The GLBA oceanographic monitoring protocol (Danielson et al. 2010) summarizes the purpose, design, and all methods for long-term oceanographic sampling. Oceanographic measurements collected on hydrographic surveys enable a “bottom-up” perspective of ecological relationships. Physical parameters (measured vertically throughout the water column at multiple locations) include water temperature, salinity, light, turbidity, and dissolved oxygen. These measurements characterize the environment that directly impacts both lower trophic (e.g., phytoplankton) and upper trophic (e.g., crabs, fishes, marine mammals, and birds) organisms through their influence on metabolic rates, ability to support carbon fixation through production of chlorophyll, and/or the propensity for organisms to be retained within or exported from the euphotic layer. Fluorescence measurements of chlorophyll-*a* provide an index of the phytoplankton standing

stock, which in turn forms the food base for primary consumers (zooplankton) and the subsequent cascade of carbon through trophic levels to apex predators (e.g., fishes, marine mammals and birds). Thus, observations made within this monitoring program form a foundation upon which other (e.g., habitat, population) aspects of the marine ecosystem within Glacier Bay can be evaluated.

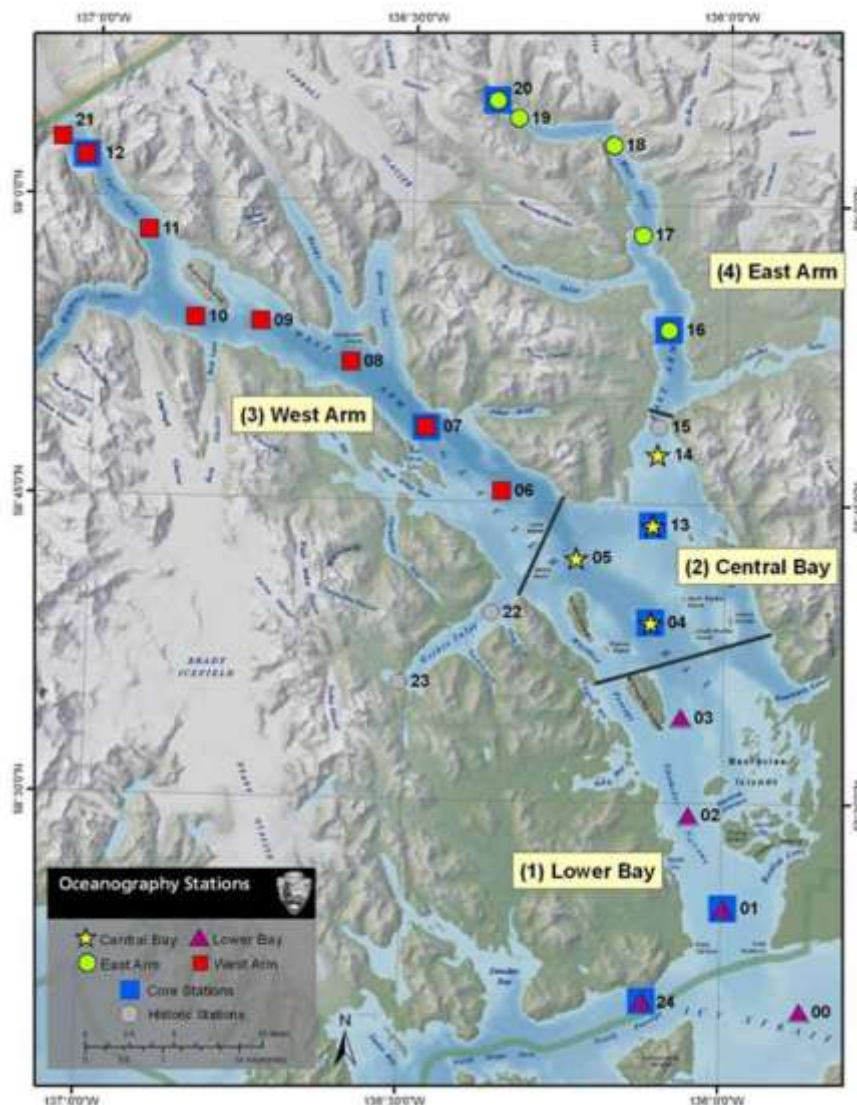
Since 1993, the NPS and the U.S. Geological Survey (USGS) have monitored oceanographic conditions at up to 24 (22 since 2009) standard stations distributed throughout Glacier Bay. Select oceanographic parameters have been measured during periodic visits to those stations each year. The core suite of CTD (Conductivity-Temperature-Depth) vertical profile measurements has been supplemented with additional measurements of turbidity, photosynthetically-active radiation (PAR), and chlorophyll-*a* concentration. The entire long-term dataset, along with annual reports, peer review publications, and program evaluations are available from the SEAN oceanography webpage ([http://science.nature.nps.gov/im/units/sean/OC\\_Main.aspx](http://science.nature.nps.gov/im/units/sean/OC_Main.aspx)). In 2009, SEAN developed the current revised protocol (also available on the SEAN webpage), largely based on a previous USGS protocol (Hooge et al. 2003).

The objectives for the GLBA oceanographic monitoring program (Danielson et al. 2010) are to:

- 1) Provide a dataset on physical oceanographic conditions in Glacier Bay (water temperature, salinity, stratification, PAR, and turbidity [optical backscatterance, OBS]) that can be used to better understand seasonal and interannual changes in the estuarine dynamics of Glacier Bay and the greater Southeast Alaska oceanographic system.
- 2) Provide a baseline oceanographic dataset (water temperature, salinity, stratification, PAR, OBS, dissolved oxygen, and chlorophyll-*a* fluorescence) that can be used by biologists to understand spatial and temporal variation in the abundance patterns of a variety of organisms including phytoplankton, zooplankton, marine invertebrates, fishes, marine mammals, and seabirds of Glacier Bay.

## Methods

Nine times each year we measure a suite of oceanographic water column parameters at permanent sampling “stations” located mid-channel throughout Glacier Bay (Figure 1). There are 22 standard oceanographic stations, including two just outside the fjord mouth that provide additional information about the water flowing in and out of Glacier Bay proper. Eight stations (including Station 24, added August 2011) are sampled monthly from March through October to describe seasonal variation during times of the strongest physical structure and highest productivity. These are called the “core stations.” Twice a year, in July (mid-summer) and December/January (mid-winter), we sample the core stations and the remaining 14 stations to detect annual or longer signals. This design achieves a balance between intensive temporal sampling to resolve seasonal signals, and intensive spatial sampling to resolve annual signals and reveal long-term trends.



**Figure 1.** Oceanographic sampling stations in Glacier Bay. Shaded bathymetry indicates relative water depth (darker means deeper). Station depths range from 53 m (Station 00) to 435 m (Station 07).

Measurements are captured by an array of sensors mounted together in an instrument cluster called a CTD (Figure 2) which is lowered through the water column (“cast”) at a rate of ~1 m/sec (~0.5 m/sec through the uppermost 50 m) from the surface to just above the bottom. Parameters are measured twice per second, and the data from each cast are stored within the CTD and downloaded at the end of the survey. Together the measurements yield a vertical profile of important water column characteristics for each station location.



**Figure 2.** The CTD integrated with the new rosette bottle sampler being recovered (bottles closed, containing water samples from known discrete depths) following a cast.

Parameters (and their units of measure) include water temperature ( $^{\circ}\text{C}$ ), salinity (Practical Salinity Units or PSUs), PAR (Photosynthetically-Active Radiation portion of the light spectrum, in  $\mu\text{E}/\text{cm}^2 \cdot \text{sec}$ ), chlorophyll-*a* fluorescence (an index of chlorophyll concentration and thus phytoplankton standing stock, in  $\text{mg}/\text{m}^3$ ), OBS (Optical Backscatterance or turbidity, in Nephelometric Turbidity Units or NTUs), and dissolved oxygen concentration ( $\text{ml}/\text{l}$  - starting with the June 2009 survey). A strain gauge continuously records water pressure which is converted to depth in meters. Measurements of temperature and salinity are subsequently analyzed together to calculate density ( $\sigma\text{-}t$ ,  $\text{kg}/\text{m}^3$ ) and vertical density gradient ( $\text{kg}/\text{m}^3/\text{m} = \text{kg}/\text{m}^4$ , a measure of the rate of change in density with depth which describes stratification relative intensity and indicates the vertical location of the pycnocline). Raw data for all parameters are processed and verified following each sampling survey (referred to as a “cruise”).

Detailed field data collection and data processing/management methods are documented in the SEAN oceanography monitoring protocol (Danielson et al. 2010).

The cycles of phytoplankton bloom and decline are unavoidably aliased with this (monthly) monitoring program. In addition, the phytoplankton assemblage being measured at any given place and time is ephemeral; the same measurement taken a day, a week, or two weeks earlier or later could bear little or no resemblance to the measurements taken on the date of the cruise. Because water column samples of phytoplankton, suspended particulates, and dissolved oxygen are not collected and analyzed, data from these ancillary sensors cannot be quantitatively compared on an inter-cruise or inter-annual basis, nor even at times within the same cruise/survey because many factors, including differing phytoplankton species assemblages and the state of health of the cells also impact the fluorescence response. Nevertheless, with these caveats in mind, we can still recognize coarse patterns and gross trends because 1) high-latitude glacial fjords typically exhibit relatively strong seasonal and inter-annual signals, and 2) expected parameter trends along the length-of-fjord transect are generally well understood (Syvitsky et al. 1987).

Starting with the July, 2011 cruise, monthly oceanographic surveys became operationally connected to a three-year research project investigating ocean acidification in Glacier Bay. Figure 2 shows how the CTD was incorporated into a steel frame supporting six water sampling bottles that are programmed to close at pre-determined depths at each station, from the surface to near the bottom. These discrete water samples open the way to a powerful suite of observations that will increase our understanding of Glacier Bay oceanography. Known-depth water samples collected simultaneously with CTD measurements are analyzed for a variety of metrics important to understanding ocean acidification and the macronutrient chemistry that supports the Glacier Bay food web. Among these discrete samples are several that are useful for field calibration of the monitoring program's oceanographic sensors, including direct measurements of salinity, dissolved oxygen, and total suspended particulates. These will improve our understanding of how accurately the instruments on the CTD array measure oceanographic parameters (salinity, dissolved oxygen, and turbidity). Water samples also allow for analyses of biologically-important nutrient concentrations, and those metrics will complement this program's fluorometry (chlorophyll-*a*) measurements to our enhance understanding of primary production and phytoplankton dynamics. These samples are collected on every cast (at every station) and on every cruise, and will continue through July 2012, and thereafter during the twice-yearly "all-stations" cruises in mid-winter and mid-July through 2014. Results from these water sample analyses will be reported separately.





## Results

### Coverage

Table 1 shows the sampling coverage across the 2011 cruise year. All target stations were successfully occupied during all cruises, except for Stations 01 and 24 in September due to rough seas. Starting with the August cruise, Station 24 was formally designated a core station.

**Table 1.** Sampling coverage of oceanographic stations during the 2011 cruise year. **Red** identifies the seven “core stations” (01, 04, 07, 12, 13, 16, 20); note that Station 24 became a core station starting with the August cruise.

Station	Mid-winter <sup>1</sup>	March <sup>2</sup>	April	May	June <sup>3</sup>	Mid-July	August	September	October <sup>4</sup>
00	X					X			
01	X	X	X	X	X	X	X		X
02	X					X			
03	X					X			
04	X	X	X	X	X	X	X	X	X
05	X					X			
06	X					X			
07	X	X	X	X	X	X	X	X	X
08	X					X			
09	X					X			
10	X					X			
11	X					X			
12	X	X	X	X	X	X	X	X	X
13	X	X	X	X	X	X	X	X	X
14	X					X			
16	X	X	X	X	X	X	X	X	X
17	X					X			
18	X					X			
19	X					X			
20	X	X	X	X	X	X	X	X	X
21	X					X			
24	X					X	X		X

<sup>1</sup> Although all stations were successfully occupied during the mid-winter (late January) cruise, all cast data from the cruise were disqualified. See Operations section.

<sup>2</sup> The March cruise was delayed by several days due to personnel availability. See Operations section.

<sup>3</sup> The “June” cruise was actually conducted on May 31. See Operations section.

<sup>4</sup> The October cruise was delayed by several days due to poor weather and personnel availability. See Operations section.

### Operations

2011 was a highly successful year in terms of the ability to occupy stations as scheduled. Presence of non-navigable pan ice was not a problem during the early-season cruises, and only once did weather preclude our ability to sample (Stations 01 and 24 in September). In order to adhere to the seasonal June 1 – July 15 non-motorized status of upper Muir Inlet, the “June” cruise actually occurred on May 31. All stations were successfully occupied during the mid-winter cruise; unfortunately, all cast data from that cruise were disqualified due to a leaky connection in the CTD which resulted in electrical noise on all sensor channels.

We were successful in securing suitable vessels and operators for the 2011 deployments. With the acquisition of the dedicated SEAN vessel R/V Fog Lark in late 2010, we had a consistently available vessel and qualified SEAN operators for the entire cruise year with one exception. Because of a temporary mechanical problem with the primary vessel, the Visitor and Resource Protection vessel Talus (with operator) was substituted for the September cruise. The March cruise (normally scheduled to occur the first full week of the month, March 6-12), was delayed until March 17 because of personnel availability. Additionally, the October cruise (normally scheduled to occur the first full week of the month, October 2-8), was delayed until October 13 because of poor weather and personnel availability.

## Observations

With a single important exception, 2011 data quality was excellent. Sensor data was complete, and post-season calibrations of all sensors indicated high sensor accuracy. Unfortunately, as described in the previous section, all cast data from the mid-winter cruise were disqualified due to a leaky connection in the CTD, which compromised data collected in all of the sensor data channels. A replacement CTD was used for the remainder of the cruise year.

Appendices A and B summarize the oceanographic parameters by core station and survey month. [Since Station 24 was not designated a “core station” until August, for purposes of this annual summary Station 24 data will not be included in the core station analysis.] Appendix A shows values averaged over the upper 0–50 m portion of the water column where the majority of primary production, macronutrient utilization, phytoplankton standing stock, thermal stratification, and low-salinity lenses occur, thus providing an integrated perspective of the most biologically active portion of the water column. Appendix B shows values that are generally descriptive of “bottom water”; these values are averaged across 10-m depth bands centered on a depth (for each station) that is well below the pycnocline yet not so deep that data are not consistently captured by casts at that station.

Appendix Table A-1 shows that in the upper 50 m of the seven core stations in 2011, mean water temperatures at all stations steadily increased from early spring minima (March-April, range ~3.3-3.7 °C) to late summer/early fall maxima (August-October, range ~7.0-8.1°C). The most rapid warming occurred in early summer, between May/June and July. Surface-water temperatures typically warmed ~3.3-4.5 °C across the season. Maximum mean values were reached in the fall (October) at the stations closest to the heads of the fjords (Stations 12, 20). In all months mean temperatures increased along the length-of-fjord gradient from the inlet heads to the mouth of the bay.

Surface-water salinity generally peaked in spring (March, range ~30.9-31.9 PSU) throughout Glacier Bay, with maximum mean values ranging from ~30.2-31.4 PSU. Salinity minima generally occurred in late summer-fall (August-October, range ~28.2-30.8 PSU). Salinities were higher throughout the year near the mouth of the bay (Stations 01, 04) and were lowest in summer-fall near the heads of inlets (Stations 12, 20).

Near-surface mean density (*sigma-t*) at all stations was highest in early spring (March-April, range ~24.6-25.3 kg/m<sup>3</sup>) with the most rapid declines generally in early summer (May-July). The former pattern closely tracked that for salinity and reflects the influence of warming (by incoming solar radiation) and freshening (by snowmelt and precipitation) that occurs between

spring and fall. Minimum mean densities generally occurred in fall (September-October, range ~22.1-24.1 kg/m<sup>3</sup>). Density was highest throughout the year at the mouth of the bay (Station 01). The depth of maximum vertical density gradient is a reasonable proxy for pycnocline depth, where the water density (*sigma-t*) changes most rapidly. At most stations in most months this depth was in the upper 10 m. The deepest occurred in late spring (March-April) in the lower bay (Stations 01, 04) and mid-West Arm (Station 07) at depths of 22-153 m.

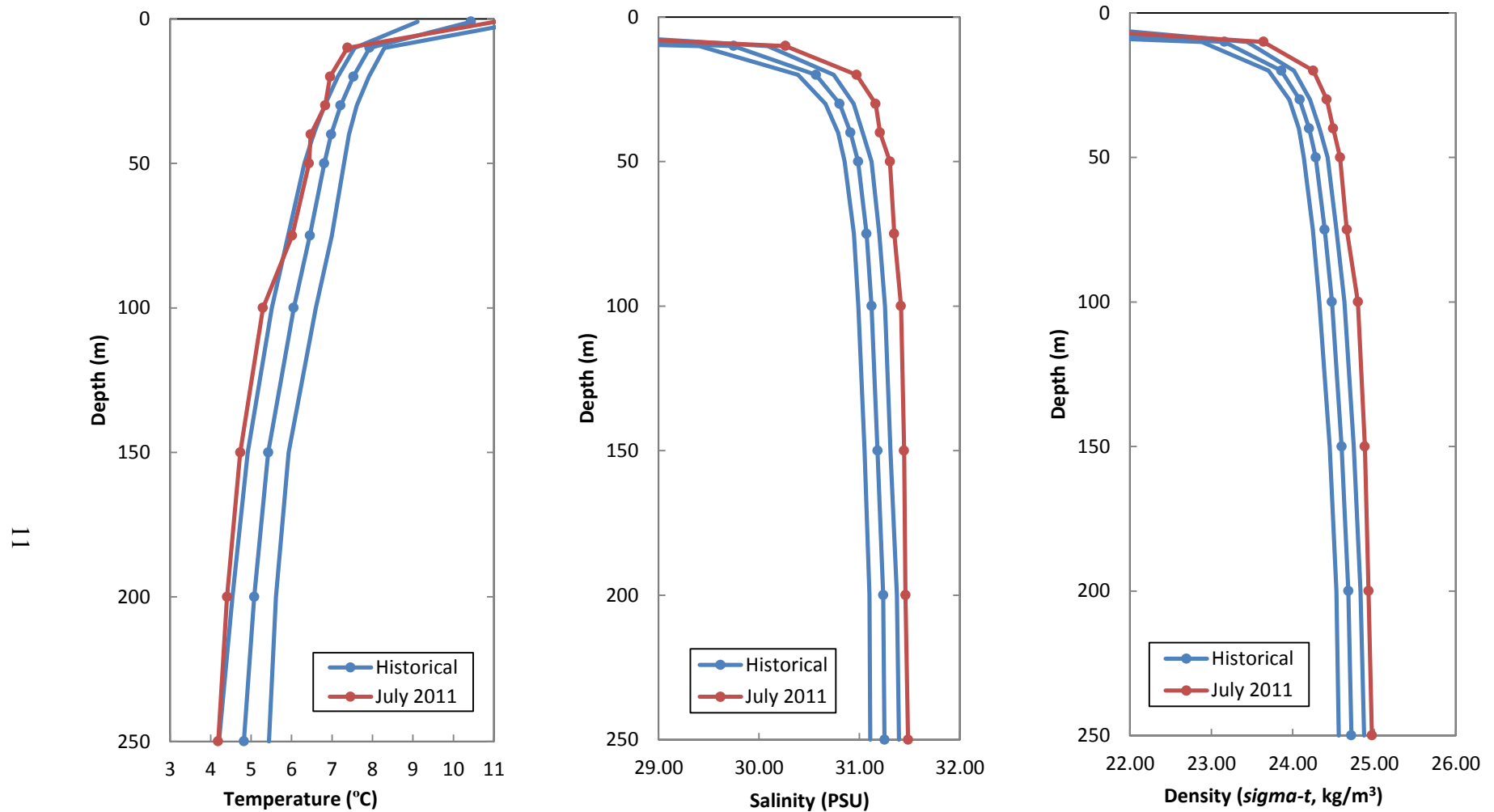
Appendix Table A-2 shows that, in the upper 50 m of the seven core stations in 2011, mean values for fluorescence (index of chlorophyll-*a* concentration) at most stations peaked in late spring – early summer (April–June), but the maxima in the lower bay (Stations 01 and 04) occurred in July and August, respectively. Peak fluorescence mean values ranged from ~0.5–1.8 mg/m<sup>3</sup> and were variable along the length-of-bay transect, albeit lower at the heads of the inlets (Stations 12, 20). Minima (range ~0.05-0.15 mg/m<sup>3</sup>) occurred in March at all stations. Closely mirroring this pattern, mean dissolved oxygen concentrations were generally highest in April–June (range ~6.7–7.6 ml/L) at all stations, and lowest in October (range ~4.5-5.6 ml/L). The lowest minima and maxima occurred at the mouth of the bay (Station 01), and the highest minima and maxima occurred at the head of the East Arm (Station 20). Mean surface-water turbidity values varied throughout the year (range ~1.3-56.7 NTU; generally <2.0 NTU), although the highest values were at the stations closest to the heads of the fjords (Stations 12, 20), and they occurred mid-summer – early fall (July–September) at those stations. As might be expected, mean PAR values through the upper 50 m were highly variable across months and stations, with minimum values approaching 0 µE/cm<sup>2</sup>\*sec, and maxima exceeding 50 µE/cm<sup>2</sup>\*sec. Note that PAR values are sensitive to boat shadows, sky cloudiness, and sun elevation, along with water column effects. In general, the highest values occurred in spring-summer (March–August), and the lowest values occurred in late summer–fall (September–October). Stations 12 and 20 (closest to glacial melt discharge) reported the very lowest minimum values during this period.

Appendix Table B-1 shows that, for the bottom water at the seven core stations in 2011, mean water temperatures generally increased throughout the year in a pattern similar to that of the surface waters, from early spring minima (March, range ~3.4-3.7 °C) to fall maxima (October, range ~4.8-8.0 °C). Bottom-water temperatures typically warmed ~1.3-4.3 °C across the season. Mean temperatures were not clearly associated with relative position along the length-of-bay gradient, as they were in the surface waters. Bottom-water mean salinity generally peaked (range ~31.4-32.0 PSU) in late spring-summer (May–July) throughout Glacier Bay. Mean salinity minima occurred in fall (October, also March at Station 16) throughout Glacier Bay; values ranged from ~30.5–31.1 PSU. Similar to the near-surface (upper 50 m) waters, bottom-water minimum mean density (*sigma-t*) occurred in fall (October) throughout Glacier Bay (range ~23.9-24.6 kg/m<sup>3</sup>), and maxima occurred in spring (April–June, range ~24.9-25.3 kg/m<sup>3</sup>). Bottom-water fluorescence (chlorophyll-*a* concentration) measurements were very low (<0.2 mg/m<sup>3</sup>) throughout the year at all stations except for Station 01 at the mouth of the bay (ranges were ~0.2-0.5 mg/m<sup>3</sup> in all months). Despite the low values, maxima consistently occurred in April (July for Station 01).

Appendix Table B-2 shows that, for the bottom water at the seven core stations in 2011, mean dissolved oxygen concentrations were generally highest in early spring (March–April, range ~6.7-6.8 ml/L) and lowest in October (range ~4.5-5.9 ml/L). There was no discernible

relationship with position along the length-of-bay transect, except that the lowest fall minimum occurred at the mouth of the bay (Station 01). These patterns are similar to those observed in the surface waters, although the bottom-water maxima were slightly earlier in the year. Patterns of bottom-water mean turbidity were very similar to those in the surface waters. Values varied throughout the year and across stations (range ~1.0-45.9 NTU; generally <2.0 NTU), although the highest values were nearest the heads of the inlets (Stations 12, 20) and occurred July-September. With very few exceptions (very low measurements at the shallow Station 01), the PAR sensor returned values of 0.00  $\mu\text{E}/\text{cm}^2\cdot\text{sec}$  for bottom-water measurements at all stations and all months.

Figure 3 provides example vertical profiles of temperature, salinity, and density from a single mid-bay station (Station 04; see Figure 2) during the month of July, 2011, plotted alongside the historical mean values for the same parameters from this station in July for the period of 1993 through 2010. This station and month were identified in the oceanographic monitoring protocol for greater in-depth analysis on a yearly basis.



**Figure 3.** Vertical profiles of temperature (left), salinity (center), and density ( $\sigma$ -t, right) shown along with historical data (means for July 1993–2010, Station 04). 2011 data are shown in **red with dots**; historical means are **blue with dots** along with  $\pm$  bounds of one standard deviation to either side (**blue**, without dots). Only a subset of the full vertical profile is shown here, using standard depths of 0, 10, 20, 30, 50, 75, 100, 150, 200, and 250 m.

We describe current-year data as “normal” when the data values fall within one standard deviation of the historical mean (1993–2010) and anomalous otherwise. Figure 3 clearly shows that waters at this station in July of 2011 were anomalously cold, salty, and dense below the upper 10 m.

Table 2 displays the numerical values plotted in Figure 3.

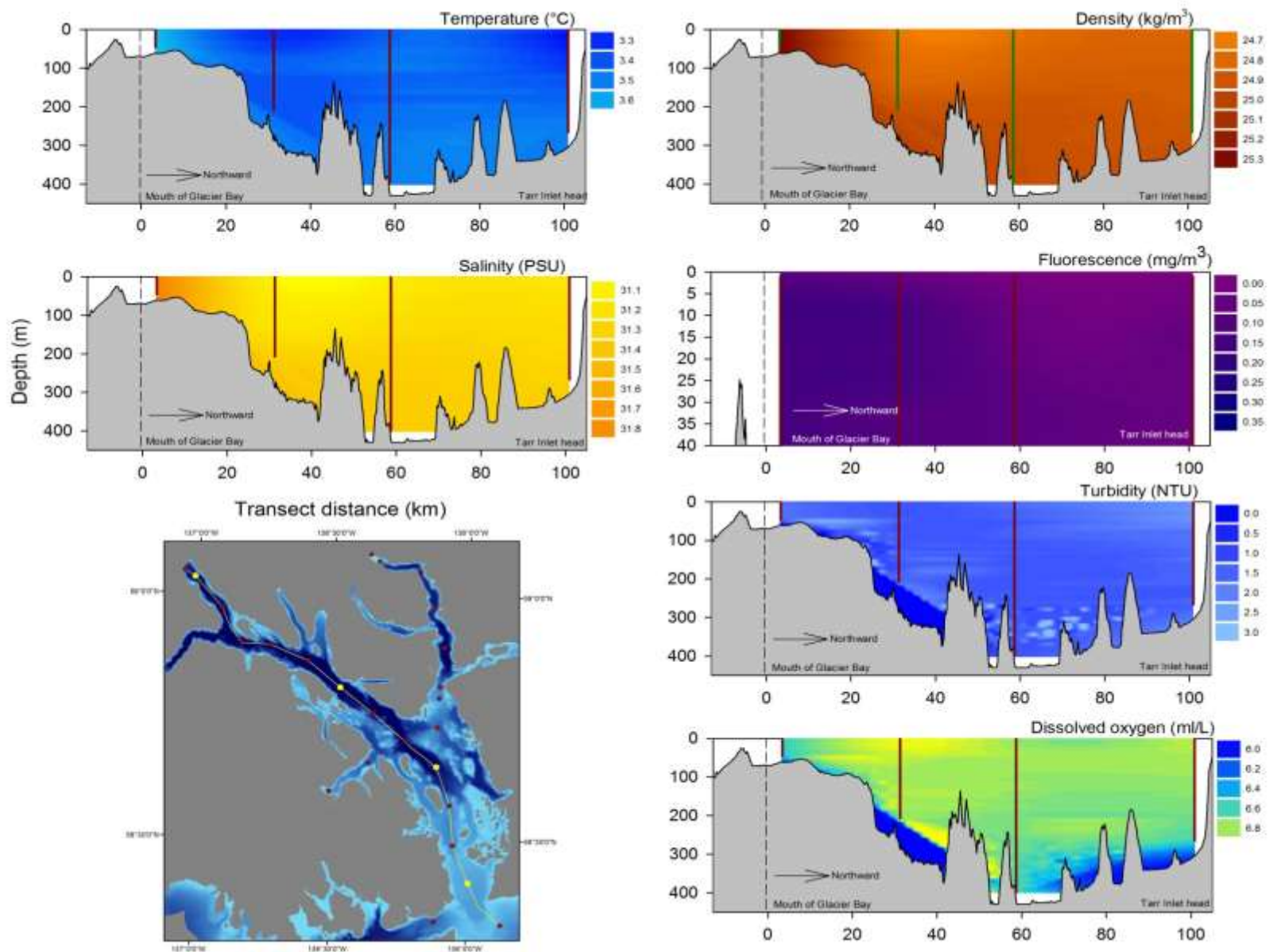
**Table 2.** Temperature, salinity, and density measurements from standard depths at Station 04 in July 2011, compared to historical measurements from that station in July, 1993–2010. To help draw attention to anomalous measurements, July 2011 observations lying outside one standard deviation (SD) of the long-term mean are emphasized in ***bold, italic type***. n = sample size.

Depth (m)	Station 04 Temperature (°C)					Station 04 Salinity (PSU)					Station 04 Density (kg/m <sup>3</sup> )				
	July 2011	Historic July mean	Historic mean -1 SD	Historic mean +1 SD	n	July 2011	Historic July mean	Historic mean -1 SD	Historic mean +1 SD	n	July 2011	Historic July mean	Historic mean -1 SD	Historic mean +1 SD	n
1	11.04	10.44	9.11	11.76	15	24.62	22.59	19.30	25.88	15	18.70	17.21	14.57	19.86	15
10	<b><i>7.38</i></b>	7.93	7.56	8.30	15	<b><i>30.26</i></b>	29.75	29.41	30.09	15	<b><i>23.64</i></b>	23.16	22.88	23.44	15
20	<b><i>6.95</i></b>	7.53	7.15	7.91	15	<b><i>30.97</i></b>	30.57	30.39	30.75	15	<b><i>24.25</i></b>	23.86	23.70	24.01	15
30	6.83	7.21	6.82	7.61	15	<b><i>31.16</i></b>	30.80	30.66	30.94	15	<b><i>24.42</i></b>	24.09	23.96	24.21	15
40	<b><i>6.47</i></b>	6.98	6.54	7.42	15	<b><i>31.20</i></b>	30.91	30.79	31.03	15	<b><i>24.50</i></b>	24.20	24.07	24.33	15
50	6.43	6.81	6.32	7.30	15	<b><i>31.30</i></b>	30.99	30.85	31.12	15	<b><i>24.58</i></b>	24.28	24.14	24.43	15
75	6.02	6.45	5.91	7.00	15	<b><i>31.35</i></b>	31.07	30.94	31.20	15	<b><i>24.66</i></b>	24.39	24.25	24.54	15
100	<b><i>5.29</i></b>	6.06	5.51	6.60	14	<b><i>31.41</i></b>	31.12	30.99	31.25	14	<b><i>24.80</i></b>	24.48	24.33	24.63	14
150	<b><i>4.73</i></b>	5.42	4.92	5.93	14	<b><i>31.44</i></b>	31.18	31.05	31.31	14	<b><i>24.89</i></b>	24.60	24.45	24.75	14
200	<b><i>4.41</i></b>	5.08	4.54	5.61	13	<b><i>31.46</i></b>	31.24	31.10	31.37	13	<b><i>24.93</i></b>	24.68	24.54	24.83	13
250	<b><i>4.19</i></b>	4.82	4.21	5.44	7	<b><i>31.48</i></b>	31.25	31.11	31.39	7	<b><i>24.97</i></b>	24.72	24.56	24.88	7

<sup>1</sup>The standard depth of 0 m has been replaced by 1 m to provide complete and consistent data for analysis. Given the objective of characterizing the surface water, 1 m is a reasonable proxy for 0 m.

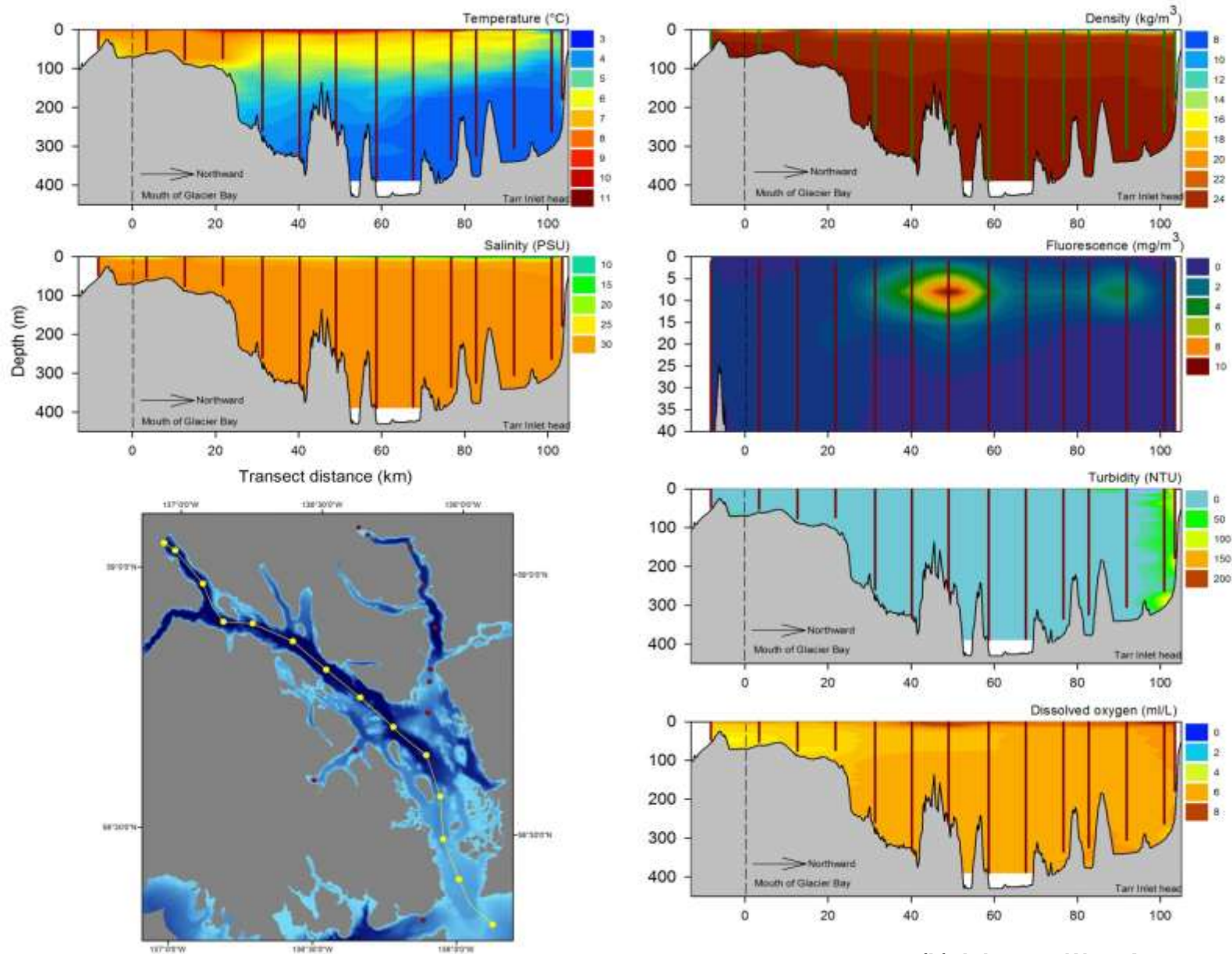
Horizontal cross-sections provide effective at-a-glance visual depictions of water column parameters as a function of depth and distance along the transect. Figure 4 shows colored contour plots of two length-of-bay transects at two different times of year. These plots incorporate data from all stations along their respective transects. All 22 oceanographic stations were occupied during the mid-summer (July) cruise; it is possible that “mid-winter” cruise conditions may be reasonably represented by core station data from the March cruise.

**Figure 4** (next two pages). Length-of-transect cross-sectional contour plots of principal oceanographic parameters for the West Arm transect for (a) March 2011, and (b) July 2011. The depth-shaded maps at bottom-left show station locations (colored dots), and transects are represented by the yellow line and use cast data from the yellow-dotted stations. On the contour plots, note the representation of the bottom (exaggerated by the depth/distance axes) along the transect line. Vertical lines indicate station locations and maximum cast depths. Use caution in interpretation: note that data are interpolated horizontally between adjacent casts, and that there are **no** data from depths beneath the bottoms of casts (notwithstanding the appearance of color). Also, note the foreshortened depth scale (upper 40 m only) for the Fluorescence parameter for both March and July.



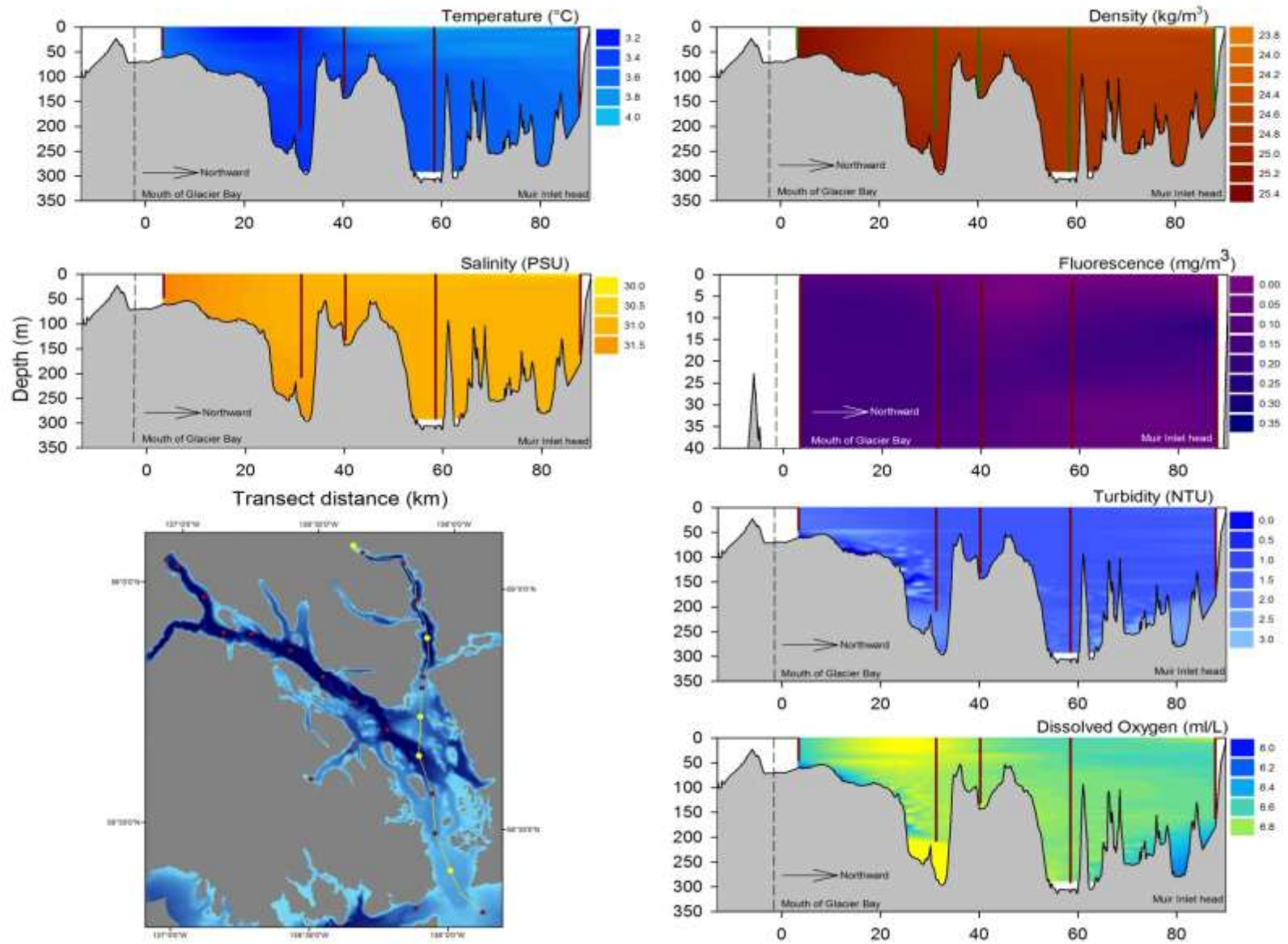
(a) March 2011 West Arm



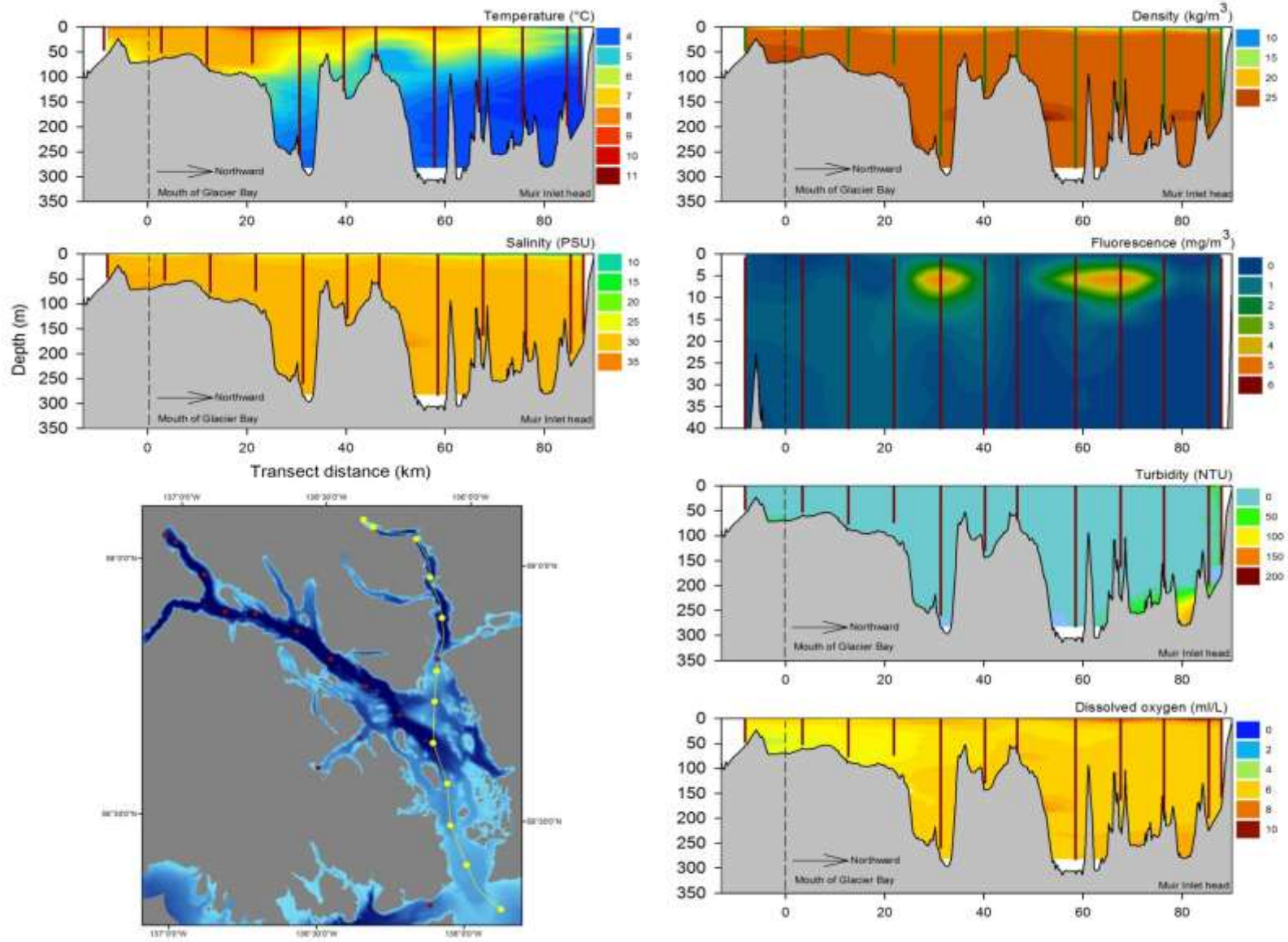


(b) July 2011 West Arm

**Figure 5** (next two pages). Length-of-transect cross-sectional contour plots of principal oceanographic parameters for the East Arm transect for (a) March 2011, and (b) July 2011. The depth-shaded maps at bottom-left show station locations (colored dots), and transects are represented by the yellow line and use cast data from the yellow-dotted stations. On the contour plots, note the representation of the bottom (exaggerated by the depth/distance axes) along the transect line. Vertical lines indicate station locations and maximum cast depths. Use caution in interpretation: note that data are interpolated horizontally between adjacent casts, and that there are **no** data from depths beneath the bottoms of casts (notwithstanding the appearance of color). Also, note the foreshortened depth scale (upper 40 m only) for the Fluorescence parameter for both March and July.



(a) March 2011 East Arm



(b) July 2011 East Arm

Figure 4a (West Arm transect in March, 2011) shows relatively cool (3.3-3.6 °C) temperatures throughout the water column at all stations, especially when compared to the data from the same (“winter”) cruise in 2010 (3.5-5.0 °C; Sharman 2013). A region of slightly warmer water occupies the extreme lower (and shallower) bay near the mouth. Salinity and density were both generally high (>31.0 PSU; >24.6 kg/m<sup>3</sup>) throughout the water column and across the entire transect, with a region of slightly lower salinity and density (corresponding to warmer water temperature) at the shallow stations in Icy Strait. There was no strong near-surface pycnocline evident, and the water column could be described as quite well mixed. Fluorescence and turbidity were both very low (<0.2 mg/m<sup>3</sup>; <3.0 NTU) at all stations and depths. Turbidity was slightly elevated in the upper 50 m near the head of the fjord; caution should be used in interpreting apparent variations between widely spaced stations, and certainly below the maximum depths of casts where there are no data. This goes for dissolved oxygen concentration patterns, too, although in general the entire water column appears to be well oxygenated along the entire transect. Again, any interpretations of horizontal length-of-transect patterns should be made cautiously for both this and the East Arm transect, since data are interpolated from a very small number of casts (four for the West Arm; five for the East Arm) across a long distance. Small features associated with local runoff or bathymetric variations are not resolved with the monitoring program.

By July (Figure 4b), West Arm temperatures were substantially warmer down to at least 100 m depth at most stations, and we observed considerable vertical structure along the entire transect. Increased temperatures and decreased salinities were most noticeable in the surface waters, and a strong near-surface pycnocline had developed in the upper 10-20 m along the entire transect. Bloom conditions were locally established, with moderate (to 10 mg/m<sup>3</sup>) levels of fluorescence concentrated in near-surface waters (generally 5-15 m; note the change in the vertical depth axis) of the mid-bay and in the upper fjord. Turbidity was again quite low except at the extreme head of the inlet (all depths). Dissolved oxygen concentrations remained high across the entire transect (highest in the surface waters), with slightly depressed values in the lower bay; there were nowhere any indications of anoxia at depth.

The East Arm transect in March (Figure 5a) strongly resembles the West Arm transect for that month (Figure 4a). The water column was quite well-mixed. As with the West Arm transect in March, fluorescence and turbidity levels were generally low at all depths and across all stations. Dissolved oxygen concentrations were high.

Figure 5b shows conditions along the East Arm transect in mid-summer (July). As with the mid-summer West Arm transect, compared to March conditions the water temperatures had warmed considerably, surface salinities had declined, and near-surface stratification was well-developed. Low levels of fluorescence were evident except near the surface (5-15 m) at localized “hotspots” in the mid-bay and in lower Muir Inlet. Turbidity levels were higher at the extreme upper inlet than in March. Dissolved oxygen was high across the entire transect, especially near the surface in the upper transect; there were no indications of anoxia at depth.





## Discussion

Oceanographic parameters are measured by sensors that are very precise and have very high calibrated accuracy. In cases where sensors do not directly measure parameters of interest (e.g., suspended particulate concentration), they have been shown to measure a closely correlated proxy (e.g., optical backscatterance, or turbidity). However, it is important to understand that because water column samples of phytoplankton, suspended sediment, and dissolved oxygen are not collected and analyzed, data from these ancillary sensors cannot be quantitatively compared with high rigor on an inter-cruise or inter-annual basis, nor even at times within the same cruise/survey because many factors, including differing phytoplankton species assemblages and the state of health of the cells also impact the fluorescence response. The cycles of phytoplankton bloom and decline are unavoidably aliased with this (monthly) monitoring program. In addition, the phytoplankton assemblage being measured at any given place and time is ephemeral; the same measurement taken a day, a week, or two weeks earlier or later could bear little or no resemblance to the measurements taken on the date of the cruise. Nevertheless, with these caveats in mind, we can still recognize coarse patterns and gross trends because 1) high-latitude glacial fjords typically exhibit relatively strong seasonal and inter-annual signals, and 2) expected parameter trends along the length-of-fjord transect are generally well understood (Syvitsky et al. 1987).

At first glance, most measured parameters in 2011 did not appear to exhibit extreme departures from the range of variation observed in Glacier Bay in previous years (Etherington et al. 2007, Sharman 2011, Sharman 2013). The standard data analysis protocol calls for closer inspection of data from the mid-summer (July) cast data from Station 04 in the central bay. In 2011 this analysis showed that waters in that location at that time were anomalously cold, salty, and dense below the upper 10 m in mid-summer (Figure 3; Table 2), compared to the 1993–2010 historical mean. This stands in contrast to the 2010 sampling year in which the same station at the same time yielded a pattern that was anomalously warm, fresh, and low-density (Sharman 2013). The difference is large in terms of changes in heat and fresh water content, with means (from standard depths below 40 m) from 2010 and 2011 varying by approximately 0.9–1.6°C for temperature, 0.39–0.47 PSU for salinity, and 0.43–0.56 kg/m<sup>3</sup> for density. The 2011 anomaly closely resembles a similar cold, salty, dense anomaly observed at the same station at the same time of year in 2009 (Sharman 2011). While the pattern of warm-cool-warm temperature anomalies was also observed in the 2009–2011 measurements made at oceanographic station GAK1 in the northern Gulf of Alaska (<http://www.ims.uaf.edu/gak1/>), the GAK1 salinity anomalies were not so clearly in phase with the Glacier Bay measurements and out of phase with the GAK1 temperatures. See Janout et al. (2010, 2013) for recent discussions of heat and fresh water content in the Gulf of Alaska and at station GAK1.

Perhaps most interesting of all is the observation of a third consecutive anomalous year compared to a 18-year historical mean (16 years of measurements in the month of July). Moreover, the anomalies have swung from cold/salty/dense to warm/fresh/low-density and back to cold/salty/dense across only three years. Clearly there is a tremendous amount of natural variability from year to year in the Glacier Bay physical habitat, and these variations may be important to the greater ecosystem. For example, metabolic rates of phytoplankton and their consumers are sensitive to temperature, and standing stock (and thereby the timing and relative abundance of grazers and subsequent consumers) may be affected in part by water temperatures.

Etherington et al. (2007) and Sharman (2010) have described a generalized model for Glacier Bay oceanography and marine production that is typified by strong seasonality and high productivity. The winter condition is characterized by vertically well-mixed waters that are presumably nutrient-rich but supportive of very low primary productivity rates because of limited light (short day length) and weak physical stratification of the water column. With the onset of spring, warming temperatures and increasing input of fresh water (primarily from melting snow and glacial ice), a near-surface stratified layer is established which in the presence of increasing day lengths allows for bloom conditions and the beginning of a sustained period of primary productivity. Stratification further strengthens into the summer, but phytoplankters do not deplete nutrients in the photic zone (and suffer a “bloom crash”) everywhere because Glacier Bay’s strong tidal currents and/or possibly wind-driven upwelling continue to inject nutrients from depth – in at least some “hotspot” locations. This fine balance of maintaining near-surface stratification in the presence of just enough mixing to replenish nutrients for phytoplankton growth is the key to Glacier Bay’s overall productivity. In the fall, a combination of decreasing day length and temperatures, and possibly strong storm activity that may assist with a breakdown of surface stratification, all contribute to a decline in primary productivity that ultimately develops into the dark, well-mixed, biologically constrained winter condition.

This model is well supported by 2011 observations. The 2011 patterns of increasing temperature, salinity, and density with distance from the fjord heads along the length-of-bay transect conforms to expectations, as does the concomitant decrease in turbidity and light penetration from the surface (PAR). One expects the upper fjords to be sources of high freshwater input from melting snow and ice, including tidewater glaciers and turbid outwash streams. The modeled seasonal signal likewise is well supported by 2011 observations. Water temperatures increased from early-spring minima to late summer/fall maxima, and salinities/densities were highest in March and lowest in late summer/fall. Seasonally-driven injections of large volumes of cold, fresh, sediment-laden water should strongly influence the oceanography of the entire fjord even as the lower/central bay is closer and more integrally connected to the warmer, more saline oceanic waters of the Gulf of Alaska. Temperatures and salinities in this coastal fjord were relatively cool and fresh compared to open ocean conditions; they also exhibited larger seasonal variations than oceanic waters (see <http://www.pmel.noaa.gov/ocs/disdeld/disdeld.html> for time series data from Ocean Station P, 50°N, 145°W). Both of these patterns reflect responsiveness to the differences in their respective marine settings and how they respond to the regional weather and climate influences.

In late spring the foregoing physical patterns create near-surface density stratification with a relatively shallow pycnocline depth, generally above 20 m, that persists well into fall. 2011 fluorometry data show that phytoplankters responded by increasing primary production in a “bloom” that initiated in spring and was possibly sustained at some places all the way into the fall when physical structure began to break down and the water column became increasingly well mixed. 2011 mean fluorescence values ranged from ~0.5-1.8 mg/m<sup>3</sup> (quite similar to those observed in 2010), but were more than an order of magnitude lower than those measured in 2009 (~8-18 mg/m<sup>3</sup>). Apparently, conditions favorable to phytoplankton growth were again weaker or less common in 2011 than in 2009.

Patterns of dissolved oxygen concentration generally tracked those of fluorometry, with values highest in spring (presumably responding to high rates of primary production and the winter



preconditioning) and lowest in October (likely reflecting subsequent bacterial consumption (decomposition) of organic matter. Nevertheless, mean concentration ranges of ~4.5–6.8 ml/L throughout the water column clearly indicate that deep water renewal occurs rapidly enough to prevent anoxic conditions throughout the measured water column. The March-April oxygen concentration peak in the bottom water suggests that 2011 renewal occurred in this timeframe.



## Recommendations

The water sampling program initiated in 2011 is a very complementary addition to the oceanographic monitoring program. It provides the potential to more directly and accurately measure chlorophyll-*a* concentrations by collection of water followed by traditional filtering and digestion of phytoplankton cells to release chlorophyll that can then be quantified by regression against the fluorescence profile. Those measurements could be used to calibrate the fluorometer deployed on the CTD. Since improved understanding of Glacier Bay's biological productivity is one of the most important reasons for the oceanographic monitoring program, this opportunity should be considered

Cast depth continues to be a parameter deserving of additional consideration. On some days at some stations wind and/or current can cause the vessel to drift during the cast. This creates line angle between the surface and the CTD, making for a cast that may be significantly shallower than the target depth (currently based solely on the length of line cast over the side). In some cases this can also mean that the target "standard oceanographic depth" determined to represent "bottom water" for a given station may not be reached by the CTD. In cases where there is significant line angle (e.g., more than thirty degrees from vertical), we should consider increasing the length of line over the side to compensate and assist with approaching the target depth. It is recommended that this issue be addressed in the upcoming protocol revision.

Note on the loss of data from December 2010: to avoid such data losses in the future, it is possible to conduct the CTD profile using a conducting-wire winch in order to view the profile data in "real time" as the CTD is lowered through the water. Data quality problems can be identified and addressed much more quickly in this fashion. This would require additional investment in equipment by NPS but would increase data quality and reliability. In addition, a conducting winch and real-time readout would allow the operator to reliably achieve the target sampling depth at each station (problem noted above) and sample closer to the bottom on all casts, which would provide additional benefits from a data and analysis standpoint.



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**Appendix A: 2011 oceanographic data summary of measured parameters at core stations, averaged across the upper 50 m of the water column.**

**Table A-1.** 2011 oceanographic data summary of measured parameters (temperature, salinity, density, and vertical density gradient) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; “SD” = standard deviation; n = sample size. Note the absence of standard deviation statistics for vertical density gradient (noisy parameter and dangerous to attempt to read too much into it). Data from the December/January “mid-winter” cruise are not displayed; those data were disqualified due to a leaky connection in the CTD. Lack of cast data for Station 01 in September due to inability to occupy stations because of rough seas.

Station	Month	Temperature (°C)					Salinity (PSU)					Density (kg/m <sup>3</sup> )					Vertical Density Gradient (kg/m <sup>4</sup> )			
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	n	Max	Depth of max (m)
01	Mar	3.68	3.66	3.68	0.01	47	31.89	31.86	31.89	0.01	47	25.34	25.32	25.35	0.01	47	0.00	45	0.01	2
	Apr	4.12	4.12	4.12	0.00	45	31.62	31.61	31.62	0.00	45	25.09	25.08	25.09	0.00	45	0.00	43	0.00	28
	May-Jun <sup>1</sup>	5.82	5.35	6.25	0.43	98	31.69	31.55	31.83	0.11	98	24.96	24.80	25.12	0.14	98	0.00	94	0.02	7
	Jul	7.40	7.28	8.57	0.17	51	31.36	19.93	32.03	1.67	51	24.50	15.39	25.03	1.33	51	0.10	51	4.46	1
	Aug	8.09	7.98	8.82	0.22	51	31.48	30.42	31.67	0.34	51	24.50	23.56	24.66	0.30	51	0.02	49	0.15	2
	Sep																			
	Oct	7.36	7.35	7.36	0.00	51	30.79	30.68	30.84	0.05	51	24.06	23.97	24.10	0.04	51	0.00	52	0.02	10
04	Mar	3.33	3.30	3.36	0.02	51	31.10	31.08	31.13	0.02	51	24.74	24.73	24.77	0.02	51	0.00	206	0.01	153
	Apr	3.63	3.52	3.75	0.08	51	31.11	30.97	31.30	0.12	51	24.73	24.60	24.88	0.10	51	0.00	251	0.02	22
	May-Jun <sup>1</sup>	5.24	4.25	9.58	0.93	102	31.08	27.17	31.57	0.78	102	24.54	20.91	24.95	0.72	102	0.01	493	0.89	2
	Jul	7.31	6.43	11.04	1.21	51	30.28	24.62	31.31	1.88	51	23.66	18.70	24.58	1.64	51	0.02	258	1.17	4
	Aug	7.78	7.18	11.23	0.88	51	29.88	22.08	31.01	2.03	51	23.29	16.70	24.26	1.71	51	0.03	262	1.81	2
	Sep	7.58	7.35	8.25	0.28	51	29.34	23.43	30.47	2.07	51	22.89	18.17	23.80	1.66	51	0.03	254	1.61	5
	Oct	7.26	7.22	7.29	0.02	51	29.28	27.62	29.96	0.71	51	22.88	21.58	23.42	0.56	51	0.01	264	0.14	7
07	Mar	3.45	3.44	3.48	0.01	51	31.15	31.14	31.18	0.01	51	24.77	24.77	24.79	0.01	51	0.00	400	0.00	55
	Apr	3.62	3.49	3.87	0.14	51	31.11	30.81	31.29	0.17	51	24.72	24.47	24.88	0.15	51	0.00	395	0.03	13
	May-Jun <sup>1</sup>	4.75	3.81	9.72	1.19	102	30.88	23.58	31.43	1.26	102	24.43	18.09	24.92	1.12	102	0.01	783	2.00	2
	Jul	6.99	6.31	10.01	0.82	51	29.35	15.45	31.22	3.95	51	22.98	11.73	24.53	3.19	51	0.03	389	2.44	3
	Aug	7.37	6.82	9.14	0.63	51	29.61	14.87	31.00	3.32	51	23.13	11.39	24.29	2.66	51	0.03	399	4.43	2
	Sep	7.59	7.03	8.07	0.24	51	28.47	13.41	30.49	3.61	51	22.20	10.45	23.83	2.83	51	0.04	375	2.31	1
	Oct	7.29	6.71	7.39	0.16	51	29.29	25.56	30.09	1.21	51	22.88	20.02	23.51	0.93	51	0.01	406	0.43	3
12	Mar	3.26	3.22	3.30	0.02	51	31.19	31.17	31.22	0.02	51	24.82	24.80	24.84	0.01	51	0.00	265	0.00	10
	Apr	3.45	3.33	3.63	0.11	51	30.89	30.16	31.24	0.36	51	24.57	24.00	24.86	0.28	51	0.00	212	0.08	6
	May-Jun <sup>1</sup>	3.78	3.18	7.61	0.78	102	30.60	18.97	31.33	2.00	102	24.31	15.09	24.91	1.62	102	0.03	513	4.15	2
	Jul	5.20	3.36	5.98	0.54	51	28.53	10.16	30.90	5.11	51	22.52	8.07	24.39	4.00	51	0.06	262	2.82	4
	Aug	5.89	4.08	6.59	0.45	51	28.83	9.46	30.74	4.65	51	22.69	7.53	24.21	3.65	51	0.07	262	4.79	2
	Sep	6.82	5.31	7.24	0.41	51	28.55	15.56	30.49	3.91	51	22.37	12.26	23.93	3.05	51	0.06	216	2.79	3
	Oct	7.29	6.40	7.41	0.22	51	29.50	25.57	30.10	1.00	51	23.05	20.07	23.53	0.76	51	0.02	266	0.84	2

<sup>1</sup>To avoid conflicting with the June 1 – July 15 closure of upper Muir Inlet to motorized access, the “June” sampling date was actually May 31; hence data from May and June cruises are averaged together.



**Table A-1 (continued).** 2011 oceanographic data summary of measured parameters (temperature, salinity, density, and vertical density gradient) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; “SD” = standard deviation; n = sample size. Note the absence of standard deviation statistics for vertical density gradient (noisy parameter and dangerous to attempt to read too much into it). Data from the December/January “mid-winter” cruise are not displayed; those data were disqualified due to a leaky connection in the CTD.

Station	Month	Temperature (°C)					Salinity (PSU)					Density (kg/m <sup>3</sup> )					Vertical Density Gradient (kg/m <sup>4</sup> )			
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	n	Max	Depth of max (m)
13	Mar	3.57	3.40	3.73	0.10	51	31.04	30.97	31.17	0.06	51	24.68	24.61	24.79	0.06	51	0.00	130	0.01	26
	Apr	3.67	3.52	4.08	0.15	51	31.05	30.42	31.38	0.29	51	24.67	24.14	24.95	0.24	51	0.01	106	0.06	4
	May-Jun <sup>1</sup>	5.00	4.03	9.38	1.00	102	31.16	28.92	31.51	0.51	102	24.63	22.31	24.96	0.50	102	0.01	250	0.41	2
	Jul	7.12	6.41	8.67	0.58	51	30.40	26.32	31.20	1.39	51	23.78	20.38	24.50	1.16	51	0.03	128	0.77	6
	Aug	7.44	7.03	9.12	0.43	51	29.75	20.65	30.95	2.50	51	23.23	15.99	24.23	2.01	51	0.07	126	1.37	2
	Sep	7.46	7.23	8.07	0.21	51	29.42	23.39	30.53	2.06	51	22.97	18.22	23.87	1.63	51	0.05	120	1.75	5
	Oct	7.25	7.00	7.35	0.10	51	29.46	27.64	30.11	0.84	51	23.02	21.63	23.54	0.65	51	0.02	131	0.33	8
31 16	Mar	3.77	3.72	4.05	0.08	51	30.97	30.81	31.03	0.06	51	24.60	24.45	24.65	0.06	51	0.00	290	0.02	2
	Apr	3.72	3.53	4.28	0.18	51	30.92	29.70	31.15	0.32	51	24.57	23.54	24.77	0.27	51	0.01	262	0.28	2
	May-Jun <sup>1</sup>	4.42	3.59	10.62	1.31	102	30.82	24.35	31.33	1.20	102	24.42	18.56	24.90	1.09	102	0.02	466	1.42	2
	Jul	6.93	6.30	9.34	0.68	51	29.98	18.34	31.16	2.73	51	23.48	14.06	24.49	2.22	51	0.04	281	3.32	2
	Aug	7.13	6.45	7.87	0.37	51	29.68	16.71	31.03	2.98	51	23.22	12.96	24.36	2.37	51	0.04	283	3.73	2
	Sep	7.28	6.60	7.65	0.22	51	28.99	16.28	30.54	3.32	51	22.65	12.75	23.90	2.60	51	0.04	286	2.15	2
	Oct	7.11	6.23	7.26	0.22	51	29.26	23.51	30.15	1.58	51	22.88	18.46	23.60	1.22	51	0.02	285	1.10	2
20	Mar	3.75	3.59	3.90	0.06	51	30.89	29.78	31.03	0.29	51	24.54	23.67	24.66	0.23	51	0.01	161	0.27	2
	Apr	3.74	3.52	4.52	0.25	51	30.94	30.08	31.15	0.27	51	24.58	23.83	24.77	0.24	51	0.01	155	0.16	2
	May-Jun <sup>1</sup>	4.05	3.52	7.64	1.01	102	30.16	15.76	31.33	3.06	102	23.93	12.39	24.90	2.49	102	0.08	291	4.52	2
	Jul	5.06	4.56	6.19	0.41	51	28.55	7.83	30.93	5.87	51	22.56	6.21	24.49	4.65	51	0.12	156	4.81	4
	Aug	5.87	5.57	6.41	0.22	51	29.14	16.87	30.87	3.34	51	22.94	13.30	24.32	2.64	51	0.07	159	2.18	2
	Sep	6.51	3.61	6.90	0.65	51	28.18	10.60	30.28	4.34	51	22.10	8.45	23.76	3.37	51	0.10	165	4.35	2
	Oct	6.98	5.56	7.18	0.32	51	29.08	19.87	30.23	2.16	51	22.76	15.66	23.68	1.67	51	0.05	163	2.47	2

<sup>1</sup>To avoid conflicting with the June 1 – July 15 closure of upper Muir Inlet to motorized access, the “June” sampling date was actually May 31; hence data from May and June cruises are averaged together.

**Table A-2.** 2011 oceanographic data summary of measured parameters (fluorescence, dissolved oxygen, OBS, and PAR) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; “SD” = standard deviation; n = sample size. Note the absence of standard deviation statistics for PAR (decreases exponentially from the surface, so standard deviation has little meaning). Data from the December/January “mid-winter” cruise are not displayed; those data were disqualified due to a leaky connection in the CTD. Lack of cast data for Station 01 in September due to inability to occupy stations because of rough seas.

Station	Month	Fluorescence (mg/m <sup>3</sup> )					Dissolved Oxygen (mg/L)					OBS (NTU)					PAR (μE/cm <sup>2</sup> * s)		
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
01	Mar	0.15	0.10	0.18	0.01	47	6.57	6.55	6.58	0.01	45	1.80	1.57	2.00	0.10	47	22.60	0.00	217.48
	Apr	0.39	0.35	0.46	0.02	45	6.72	6.69	6.74	0.01	44	2.36	2.24	2.56	0.09	45	10.16	0.00	91.41
	May-Jun <sup>1</sup>	0.45	0.19	0.59	0.08	98	6.58	6.41	6.88	0.15	98	1.90	1.71	2.10	0.08	98	31.23	0.00	587.10
	Jul	0.53	0.00	0.66	0.12	51	5.31	4.91	6.56	0.34	51	2.48	1.74	11.68	1.65	51	36.67	0.00	418.18
	Aug	0.44	0.39	0.62	0.06	51	4.79	4.68	5.28	0.16	51	1.54	1.37	1.78	0.09	51	48.86	0.48	379.36
	Sep																		
	Oct	0.21	0.14	0.22	0.02	51	4.53	4.50	4.60	0.03	51	3.76	2.96	4.18	0.26	51	12.26	0.00	146.42
04	Mar	0.13	0.05	0.17	0.03	51	6.95	6.88	6.99	0.04	51	1.38	1.29	1.62	0.08	51	20.67	0.06	153.80
	Apr	1.14	0.12	2.38	0.90	51	7.08	6.78	7.44	0.25	51	1.46	1.29	1.64	0.12	51	9.60	0.00	109.35
	May-Jun <sup>1</sup>	1.33	0.06	6.76	1.85	102	7.37	6.65	10.22	0.82	102	1.56	1.10	2.76	0.38	102	37.95	0.00	903.08
	Jul	1.01	0.19	5.97	1.40	51	6.03	5.67	7.09	0.37	51	1.83	1.57	2.73	0.31	51	41.92	0.00	582.42
	Aug	1.75	0.18	13.00	2.96	51	6.30	5.47	10.01	1.38	51	1.56	1.32	2.35	0.29	51	31.17	0.00	381.91
	Sep	0.55	0.18	2.28	0.64	51	5.39	4.96	7.21	0.66	51	1.98	1.55	3.06	0.40	51	8.02	0.00	91.19
	Oct	0.36	0.21	0.65	0.14	51	5.34	5.05	6.04	0.29	51	2.15	1.80	2.53	0.17	51	11.21	0.00	80.20
07	Mar	0.07	0.00	0.10	0.03	51	6.82	6.80	6.86	0.01	51	1.56	1.26	1.85	0.13	51	42.21	0.06	380.24
	Apr	1.26	0.00	3.62	1.44	51	7.10	6.67	8.00	0.45	51	1.46	1.12	1.82	0.17	51	7.83	0.00	98.95
	May-Jun <sup>1</sup>	1.02	0.06	6.51	1.44	102	7.38	6.68	10.85	1.07	102	1.44	1.07	3.09	0.44	102	45.60	0.00	1103.20
	Jul	1.22	0.06	8.03	1.90	51	6.44	5.94	8.94	0.81	51	2.04	1.55	6.61	1.09	51	8.22	0.00	129.15
	Aug	1.09	0.06	7.14	1.66	51	6.23	5.58	10.13	1.21	51	1.81	1.33	6.38	1.10	51	25.23	0.00	392.37
	Sep	0.40	0.02	2.57	0.59	51	5.81	5.15	7.71	0.73	51	2.41	1.47	10.61	1.64	51	9.43	0.00	177.44
	Oct	0.35	0.06	1.61	0.42	51	5.25	4.92	7.08	0.56	51	1.90	1.55	2.99	0.29	51	25.02	0.00	313.89
12	Mar	0.05	0.00	0.08	0.02	51	6.86	6.81	6.89	0.02	51	2.34	2.04	2.62	0.14	51	28.56	0.00	275.02
	Apr	0.40	0.06	1.16	0.35	51	7.04	6.80	7.49	0.23	51	2.26	1.65	3.38	0.55	51	17.81	0.00	238.13
	May-Jun <sup>1</sup>	0.58	0.02	2.53	0.66	102	6.79	6.24	9.06	0.72	102	8.20	2.04	71.17	10.89	102	33.66	0.00	1106.80
	Jul	0.44	0.00	2.22	0.43	51	6.99	6.53	9.64	0.58	51	54.01	2.78	85.11	21.45	51	7.30	0.00	167.71
	Aug	0.41	0.00	5.08	1.03	51	6.90	6.25	11.07	1.22	51	15.51	6.69	30.16	5.37	51	8.66	0.00	168.88
	Sep	0.21	0.04	1.42	0.32	51	6.23	5.76	7.67	0.58	51	15.84	7.76	27.95	6.60	51	2.34	0.00	52.23
	Oct	0.15	0.00	0.65	0.18	51	5.53	5.45	6.32	0.18	51	3.23	2.23	10.21	1.84	51	2.93	0.00	51.89

<sup>1</sup>To avoid conflicting with the June 1 – July 15 closure of upper Muir Inlet to motorized access, the “June” sampling date was actually May 31; hence data from May and June cruises are averaged together.

**Table A-2 (continued).** 2011 oceanographic data summary of measured parameters (fluorescence, dissolved oxygen, OBS, and PAR) at core stations, averaged across the upper 50 m of the water column. “Min” and “max” refer to minimum and maximum data values, respectively; “SD” = standard deviation; n = sample size. Note the absence of standard deviation statistics for PAR (decreases exponentially from the surface, so standard deviation has little meaning). Data from the December/January “mid-winter” cruise are not displayed; those data were disqualified due to a leaky connection in the CTD.

Station	Month	Fluorescence (mg/m <sup>3</sup> )					Dissolved Oxygen (mg/L)					OBS (NTU)					PAR (μE/cm <sup>2</sup> * s)		
		Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
33 13	Mar	0.11	0.01	0.17	0.04	51	6.81	6.76	6.90	0.03	51	1.34	1.26	1.45	0.05	51	42.63	0.26	258.86
	Apr	1.33	0.05	4.58	1.39	51	7.12	6.73	8.28	0.45	51	1.68	1.24	2.42	0.34	51	14.13	0.00	216.10
	May-Jun <sup>1</sup>	1.11	0.04	9.99	1.90	102	7.19	6.56	10.38	0.84	102	1.55	1.13	3.38	0.44	102	18.11	0.00	241.39
	Jul	0.65	0.18	1.51	0.40	51	6.04	5.87	6.46	0.17	51	1.83	1.58	3.12	0.40	51	15.42	0.00	180.93
	Aug	1.03	0.19	4.69	1.11	51	6.13	5.56	8.40	0.88	51	1.53	1.30	2.26	0.28	51	11.15	0.00	123.94
	Sep	0.36	0.09	1.46	0.37	51	5.30	4.96	6.80	0.52	51	2.23	1.57	6.06	1.28	51	4.55	0.00	53.12
	Oct	0.24	0.12	0.46	0.11	51	5.16	4.96	5.79	0.27	51	1.96	1.74	2.75	0.31	51	4.33	0.00	47.08
33 16	Mar	0.09	0.00	0.18	0.05	51	6.66	6.58	6.68	0.03	51	1.34	1.30	1.59	0.04	51	28.11	0.16	166.61
	Apr	1.49	0.02	10.71	2.54	51	7.09	6.79	9.55	0.62	51	1.58	1.15	2.52	0.39	51	10.61	0.00	179.62
	May-Jun <sup>1</sup>	0.96	0.00	16.13	2.45	102	7.06	6.58	10.61	0.79	102	1.90	1.01	4.54	0.81	102	51.00	0.00	1168.40
	Jul	0.76	0.09	5.58	1.19	51	6.32	5.89	10.26	0.90	51	1.90	1.56	4.01	0.58	51	26.96	0.00	358.41
	Aug	0.94	0.07	4.14	1.04	51	6.21	5.58	9.67	1.09	51	1.66	1.30	4.15	0.59	51	18.88	0.00	239.69
	Sep	0.27	0.06	1.79	0.38	51	5.57	5.19	7.80	0.62	51	2.28	1.69	4.53	0.73	51	2.23	0.00	31.13
	Oct	0.16	0.03	0.42	0.13	51	5.18	5.01	6.35	0.31	51	1.88	1.53	3.24	0.42	51	6.88	0.00	77.26
20	Mar	0.10	0.00	0.33	0.08	51	6.68	6.62	6.89	0.07	51	1.47	1.19	1.63	0.12	51	38.87	0.09	326.92
	Apr	2.04	0.42	5.89	1.53	51	7.64	6.58	10.97	1.36	51	1.69	1.32	2.33	0.23	51	19.13	0.00	286.07
	May-Jun <sup>1</sup>	0.79	0.00	10.37	1.99	102	7.17	5.91	13.01	1.74	102	8.11	1.47	154.76	21.97	102	10.22	0.00	414.81
	Jul	0.32	0.09	1.67	0.31	51	6.74	6.11	9.87	1.03	51	36.66	19.29	146.43	26.21	51	0.09	0.00	2.20
	Aug	0.10	0.00	1.45	0.24	51	6.37	5.91	8.16	0.57	51	11.51	8.19	21.70	3.00	51	5.80	0.00	124.78
	Sep	0.17	0.05	0.55	0.10	51	6.22	5.80	8.46	0.61	51	56.69	14.37	101.04	29.63	51	0.15	0.00	3.86
	Oct	0.09	0.00	0.62	0.17	51	5.57	5.46	6.60	0.23	51	4.01	2.74	6.79	1.03	51	5.44	0.00	84.76

<sup>1</sup>To avoid conflicting with the June 1 – July 15 closure of upper Muir Inlet to motorized access, the “June” sampling date was actually May 31; hence data from May and June cruises are averaged together.



**Appendix B: 2011 oceanographic data summary of measured parameters at core stations, averaged across a 10-m vertical depth band centered on a representative bottom water depth for each station.**

**Table B-1.** 2011 oceanographic data summary of measured parameters (temperature, salinity, density, and fluorescence) at core stations, averaged across a 10-m vertical depth band centered on a representative bottom water depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; “SD” = standard deviation; n = sample size. Data from the December/January “mid-winter” cruise are not displayed; those data were disqualified due to a leaky connection in the CTD. Lack of cast data for Station 01 in September due to inability to occupy stations because of rough seas.

Station	Month	Depth (m)	Temperature (°C)					Salinity (PSU)					Density (kg/m <sup>3</sup> )					Fluorescence (mg/m <sup>3</sup> )				
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n
01	Mar	40	3.68	3.68	3.68	0.00	10	31.89	31.89	31.89	0.00	10	25.34	25.34	25.34	0.00	10	0.16	0.15	0.17	0.01	10
	Apr		4.12	4.12	4.12	0.00	9	31.62	31.62	31.62	0.00	9	25.09	25.09	25.09	0.00	9	0.39	0.38	0.40	0.01	9
	May-Jun <sup>1</sup>		5.82	5.38	6.25	0.44	20	31.71	31.60	31.82	0.11	20	24.97	24.84	25.11	0.14	20	0.45	0.42	0.48	0.02	20
	Jul		7.40	7.39	7.40	0.00	10	31.97	31.91	32.03	0.06	10	24.98	24.93	25.03	0.04	10	0.47	0.44	0.51	0.03	10
	Aug		7.99	7.99	7.99	0.00	10	31.66	31.66	31.66	0.00	10	24.65	24.65	24.66	0.00	10	0.41	0.40	0.43	0.01	10
	Sep																					
	Oct		7.36	7.36	7.36	0.00	10	30.81	30.80	30.82	0.01	10	24.07	24.06	24.08	0.01	10	0.21	0.21	0.22	0.00	10
04	Mar	200	3.37	3.37	3.37	0.00	10	31.32	31.31	31.32	0.00	10	24.91	24.91	24.92	0.00	10	0.06	0.06	0.07	0.00	10
	Apr		3.76	3.74	3.78	0.01	10	31.49	31.49	31.49	0.00	10	25.02	25.01	25.02	0.00	10	0.19	0.17	0.20	0.01	10
	May-Jun <sup>1</sup>		4.27	4.03	4.50	0.23	20	31.55	31.51	31.58	0.03	20	25.01	25.01	25.02	0.00	20	0.03	0.01	0.05	0.01	20
	Jul		4.41	4.38	4.42	0.01	10	31.46	31.46	31.46	0.00	10	24.93	24.93	24.93	0.00	10	0.01	0.00	0.02	0.00	10
	Aug		4.72	4.70	4.76	0.02	10	31.40	31.40	31.40	0.00	10	24.85	24.84	24.86	0.00	10	0.02	0.01	0.02	0.01	10
	Sep		5.04	4.97	5.08	0.04	10	31.30	31.29	31.31	0.00	10	24.74	24.73	24.75	0.01	10	0.01	0.01	0.02	0.00	10
	Oct		5.58	5.49	5.62	0.05	10	31.08	31.07	31.10	0.01	10	24.51	24.49	24.53	0.01	10	0.02	0.02	0.02	0.00	10
07	Mar	200	3.48	3.48	3.48	0.00	10	31.32	31.32	31.32	0.00	10	24.91	24.90	24.91	0.00	10	0.04	0.03	0.04	0.00	10
	Apr		3.62	3.62	3.62	0.00	10	31.46	31.46	31.46	0.00	10	25.01	25.01	25.01	0.00	10	0.11	0.10	0.11	0.00	10
	May-Jun <sup>1</sup>		3.79	3.63	3.94	0.16	20	31.48	31.45	31.51	0.03	20	25.01	25.00	25.02	0.01	20	0.04	0.00	0.09	0.04	20
	Jul		4.25	4.24	4.26	0.01	10	31.46	31.46	31.46	0.00	10	24.95	24.94	24.95	0.00	10	0.01	0.00	0.01	0.00	10
	Aug		4.09	4.03	4.17	0.05	10	31.35	31.35	31.36	0.00	10	24.88	24.87	24.89	0.01	10	0.02	0.01	0.03	0.01	10
	Sep		5.00	4.97	5.01	0.01	10	31.31	31.30	31.31	0.00	10	24.75	24.75	24.76	0.00	10	0.02	0.02	0.03	0.00	10
	Oct		5.76	5.66	5.82	0.05	10	31.09	31.07	31.12	0.01	10	24.50	24.47	24.53	0.02	10	0.02	0.01	0.03	0.00	10
12	Mar	200	3.47	3.47	3.47	0.00	10	31.28	31.28	31.28	0.00	10	24.88	24.88	24.88	0.00	10	0.03	0.01	0.04	0.01	10
	Apr		3.53	3.53	3.53	0.00	10	31.45	31.45	31.45	0.00	10	25.01	25.01	25.01	0.00	10	0.10	0.09	0.11	0.01	10
	May-Jun <sup>1</sup>		3.56	3.55	3.56	0.01	20	31.46	31.45	31.47	0.01	20	25.01	25.00	25.02	0.01	20	0.03	0.00	0.07	0.03	20
	Jul		3.73	3.71	3.75	0.01	10	31.30	31.29	31.32	0.01	10	24.87	24.86	24.89	0.01	10	0.10	0.09	0.12	0.01	10
	Aug		3.98	3.97	4.00	0.01	10	31.26	31.26	31.26	0.00	10	24.81	24.81	24.82	0.00	10	0.05	0.04	0.06	0.01	10
	Sep		4.24	4.22	4.28	0.02	10	31.22	31.20	31.22	0.01	10	24.76	24.74	24.76	0.01	10	0.01	0.01	0.02	0.00	10
	Oct		4.97	4.94	5.00	0.02	10	31.06	31.02	31.09	0.02	10	24.56	24.52	24.58	0.02	10	0.02	0.00	0.03	0.01	10

<sup>1</sup>To avoid conflicting with the June 1 – July 15 closure of upper Muir Inlet to motorized access, the “June” sampling date was actually May 31; hence data from May and June cruises are averaged together.

**Table B-1 (continued).** 2011 oceanographic data summary of measured parameters (temperature, salinity, density, and fluorescence) at core stations, averaged across a 10-m vertical depth band centered on a representative bottom water depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; “SD” = standard deviation; n = sample size. Data from the December/January “mid-winter” cruise are not displayed; those data were disqualified due to a leaky connection in the CTD.

Station	Month	Depth (m)	Temperature (°C)					Salinity (PSU)					Density (kg/m <sup>3</sup> )					Fluorescence (mg/m <sup>3</sup> )				
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max	SD	n
13	Mar	100	3.44	3.44	3.44	0.00	10	31.23	31.23	31.23	0.00	10	24.84	24.84	24.84	0.00	10	0.07	0.06	0.07	0.00	10
	Apr		3.75	3.74	3.76	0.00	10	31.45	31.45	31.45	0.00	10	24.99	24.98	24.99	0.00	10	0.14	0.13	0.15	0.01	10
	May-Jun <sup>1</sup>		4.70	4.31	5.12	0.39	20	31.55	31.51	31.58	0.04	20	24.97	24.96	24.98	0.01	20	0.01	0.00	0.03	0.01	20
	Jul		5.27	5.26	5.29	0.01	10	31.40	31.39	31.40	0.00	10	24.79	24.78	24.79	0.00	10	0.04	0.03	0.04	0.00	10
	Aug		6.02	5.96	6.14	0.06	10	31.22	31.21	31.23	0.01	10	24.56	24.54	24.58	0.01	10	0.07	0.05	0.08	0.01	10
	Sep		6.11	6.04	6.21	0.05	10	31.02	30.98	31.05	0.02	10	24.40	24.35	24.43	0.02	10	0.04	0.02	0.06	0.01	10
	Oct		6.78	6.74	6.84	0.03	10	30.53	30.47	30.57	0.03	10	23.93	23.88	23.96	0.03	10	0.04	0.04	0.05	0.00	10
16	Mar	200	3.53	3.53	3.53	0.00	10	31.14	31.14	31.14	0.00	10	24.76	24.76	24.76	0.00	10	0.06	0.06	0.07	0.00	10
	Apr		3.52	3.52	3.52	0.00	10	31.28	31.28	31.28	0.00	10	24.87	24.87	24.87	0.00	10	0.11	0.10	0.12	0.00	10
	May-Jun <sup>1</sup>		4.04	4.01	4.12	0.05	13	31.43	31.42	31.44	0.00	13	24.94	24.94	24.94	0.00	13	0.01	0.00	0.01	0.00	13
	Jul		3.95	3.95	3.95	0.00	10	31.38	31.38	31.38	0.00	10	24.91	24.91	24.91	0.00	10	0.01	0.00	0.02	0.00	10
	Aug		4.00	4.00	4.01	0.00	10	31.35	31.35	31.36	0.00	10	24.89	24.88	24.89	0.00	10	0.02	0.01	0.03	0.01	10
	Sep		4.32	4.32	4.34	0.01	10	31.29	31.29	31.29	0.00	10	24.80	24.80	24.81	0.00	10	0.02	0.01	0.03	0.00	10
	Oct		4.83	4.82	4.85	0.01	10	31.15	31.14	31.16	0.00	10	24.64	24.63	24.65	0.00	10	0.01	0.01	0.02	0.00	10
20	Mar	125	3.66	3.66	3.66	0.00	10	31.08	31.08	31.08	0.00	10	24.70	24.70	24.70	0.00	10	0.00	0.00	0.01	0.00	10
	Apr		3.51	3.51	3.51	0.00	10	31.23	31.22	31.23	0.00	10	24.83	24.83	24.83	0.00	10	0.17	0.15	0.20	0.02	10
	May-Jun <sup>1</sup>		3.73	3.70	3.74	0.01	20	31.36	31.35	31.37	0.00	20	24.92	24.91	24.92	0.00	20	0.01	0.00	0.02	0.00	20
	Jul		3.76	3.76	3.76	0.00	10	31.27	31.26	31.28	0.00	10	24.84	24.84	24.85	0.00	10	0.07	0.05	0.08	0.01	10
	Aug		3.93	3.91	3.94	0.01	10	31.22	31.21	31.23	0.01	10	24.79	24.78	24.80	0.01	10	0.04	0.02	0.05	0.01	10
	Sep		4.50	4.48	4.51	0.01	10	31.06	31.05	31.07	0.01	10	24.61	24.60	24.61	0.01	10	0.10	0.09	0.10	0.00	10
	Oct		5.26	5.14	5.37	0.08	10	30.96	30.93	30.99	0.02	10	24.45	24.41	24.48	0.03	10	0.01	0.00	0.02	0.00	10

<sup>1</sup>To avoid conflicting with the June 1 – July 15 closure of upper Muir Inlet to motorized access, the “June” sampling date was actually May 31; hence data from May and June cruises are averaged together.

**Table B-2.** 2011 oceanographic data summary of measured parameters (dissolved oxygen, OBS, and PAR) at core stations, averaged across a 10-m vertical depth band centered on a representative bottom water depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; “SD” = standard deviation; n = sample size. Note the absence of the SD statistic for PAR (decreases exponentially from the surface, so SD has little meaning). Data from the December/January “mid-winter” cruise are not displayed; those data were disqualified due to a leaky connection in the CTD. Lack of cast data for Station 01 in September due to inability to occupy stations because of rough seas.

Station	Month	Depth (m)	Dissolved Oxygen (mg/L)					OBS (NTU)					PAR ( $\mu\text{E}/\text{cm}^2 \cdot \text{s}$ )		
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
01	Mar	40	6.57	6.55	6.58	0.01	9	1.79	1.57	1.87	0.10	10	0.06	0.00	0.20
	Apr		6.72	6.70	6.73	0.01	8	2.35	2.28	2.50	0.07	9	0.00	0.00	0.00
	May-Jun <sup>1</sup>		6.56	6.41	6.71	0.15	20	1.90	1.81	2.07	0.07	20	0.02	0.00	0.16
	Jul		4.96	4.92	5.02	0.05	10	2.14	2.09	2.36	0.08	10	0.03	0.00	0.12
	Aug		4.70	4.69	4.71	0.01	10	1.58	1.44	1.64	0.07	10	1.75	0.94	2.83
	Sep														
	Oct		4.52	4.52	4.53	0.01	10	3.69	3.58	3.95	0.12	10	0.00	0.00	0.00
04	Mar	200	6.79	6.79	6.80	0.01	10	1.62	1.56	1.80	0.07	10	0.00	0.00	0.00
	Apr		6.67	6.66	6.69	0.01	10	1.59	1.56	1.63	0.03	10	0.00	0.00	0.00
	May-Jun <sup>1</sup>		6.69	6.55	6.85	0.14	20	1.14	1.09	1.24	0.04	20	0.00	0.00	0.00
	Jul		6.18	6.17	6.19	0.01	10	1.64	1.57	1.87	0.09	10	0.00	0.00	0.00
	Aug		5.99	5.98	6.00	0.01	10	1.80	1.65	1.92	0.09	10	0.00	0.00	0.00
	Sep		5.73	5.71	5.75	0.01	10	1.69	1.58	1.87	0.10	10	0.00	0.00	0.00
	Oct		5.44	5.42	5.47	0.02	10	2.26	2.03	2.58	0.20	10	0.00	0.00	0.00
07	Mar	200	6.73	6.72	6.74	0.01	10	1.34	1.30	1.38	0.03	10	0.00	0.00	0.00
	Apr		6.69	6.68	6.70	0.00	10	1.23	1.11	1.36	0.08	10	0.00	0.00	0.00
	May-Jun <sup>1</sup>		6.57	6.48	6.66	0.08	20	1.00	0.81	1.21	0.14	20	0.00	0.00	0.00
	Jul		6.22	6.21	6.23	0.00	10	1.64	1.59	1.79	0.07	10	0.00	0.00	0.00
	Aug		6.16	6.13	6.20	0.03	10	1.60	1.48	1.66	0.06	10	0.00	0.00	0.00
	Sep		5.83	5.80	5.86	0.02	10	1.62	1.58	1.65	0.02	10	0.00	0.00	0.00
	Oct		5.57	5.55	5.60	0.02	10	2.23	2.05	2.45	0.15	10	0.00	0.00	0.00
12	Mar	200	6.71	6.68	6.72	0.01	10	1.58	1.53	1.63	0.03	10	0.00	0.00	0.00
	Apr		6.69	6.68	6.70	0.01	10	1.30	1.07	1.38	0.10	10	0.00	0.00	0.00
	May-Jun <sup>1</sup>		6.52	6.47	6.57	0.04	20	3.27	1.76	5.06	1.33	20	0.00	0.00	0.00
	Jul		6.32	6.31	6.33	0.01	10	44.55	43.18	45.77	1.03	10	0.00	0.00	0.00
	Aug		6.23	6.22	6.24	0.01	10	22.19	20.09	24.03	1.60	10	0.00	0.00	0.00
	Sep		6.11	6.10	6.11	0.00	10	7.67	5.65	8.93	1.08	10	0.00	0.00	0.00
	Oct		5.93	5.92	5.94	0.01	10	2.46	2.25	2.80	0.21	10	0.00	0.00	0.00

<sup>1</sup>To avoid conflicting with the June 1 – July 15 closure of upper Muir Inlet to motorized access, the “June” sampling date was actually May 31; hence data from May and June cruises are averaged together.



**Table B-2 (continued).** 2011 oceanographic data summary of measured parameters (dissolved oxygen, OBS, and PAR) at core stations, averaged across a 10-m vertical depth band centered on a representative “bottom water depth for each station. “Min” and “max” refer to minimum and maximum data values, respectively; “SD” = standard deviation; n = sample size. Note the absence of the SD statistic for PAR (decreases exponentially from the surface, so SD has little meaning). Data from the December/January “mid-winter” cruise are not displayed; those data were disqualified due to a leaky connection in the CTD.

Station	Month	Depth (m)	Dissolved Oxygen (mg/L)					OBS (NTU)					PAR ( $\mu\text{E}/\text{cm}^2 \cdot \text{s}$ )		
			Mean	Min	Max	SD	n	Mean	Min	Max	SD	n	Mean	Min	Max
13	Mar	100	6.79	6.78	6.80	0.01	10	1.35	1.30	1.41	0.04	10	0.00	0.00	0.00
	Apr		6.71	6.70	6.72	0.01	9	1.54	1.45	1.64	0.06	10	0.00	0.00	0.00
	May-Jun <sup>1</sup>		6.69	6.54	6.84	0.13	20	1.15	1.11	1.25	0.03	20	0.00	0.00	0.00
	Jul		6.04	6.03	6.04	0.00	10	1.90	1.82	2.13	0.10	10	0.00	0.00	0.00
	Aug		5.64	5.63	5.66	0.01	10	1.60	1.51	1.69	0.07	10	0.00	0.00	0.00
	Sep		5.35	5.33	5.38	0.02	10	1.79	1.58	1.89	0.10	10	0.00	0.00	0.00
	Oct		5.00	4.99	5.01	0.01	10	2.04	2.01	2.09	0.03	10	0.00	0.00	0.00
16	Mar	200	6.75	6.75	6.76	0.01	10	1.46	1.35	1.58	0.07	10	0.00	0.00	0.00
	Apr		6.80	6.80	6.81	0.01	10	1.37	1.30	1.59	0.08	10	0.00	0.00	0.00
	May-Jun <sup>1</sup>		6.77	6.69	6.79	0.02	11	1.12	0.98	1.16	0.05	13	0.00	0.00	0.00
	Jul		6.36	6.35	6.37	0.01	10	1.65	1.59	1.79	0.06	10	0.00	0.00	0.00
	Aug		6.26	6.25	6.28	0.01	10	1.58	1.49	1.63	0.04	10	0.00	0.00	0.00
	Sep		5.99	5.98	6.00	0.01	10	1.62	1.56	1.78	0.06	10	0.00	0.00	0.00
	Oct		5.71	5.71	5.72	0.00	10	1.81	1.74	1.87	0.04	10	0.00	0.00	0.00
20	Mar	125	6.69	6.68	6.70	0.01	10	1.34	1.30	1.38	0.02	10	0.00	0.00	0.00
	Apr		6.81	6.79	6.82	0.01	10	1.35	1.30	1.39	0.03	10	0.00	0.00	0.00
	May-Jun <sup>1</sup>		6.56	6.50	6.61	0.04	20	3.80	1.29	7.33	2.52	20	0.00	0.00	0.00
	Jul		6.18	6.16	6.19	0.01	10	20.63	19.20	22.06	1.12	10	0.00	0.00	0.00
	Aug		6.07	6.06	6.08	0.01	10	19.62	15.77	21.70	2.17	10	0.00	0.00	0.00
	Sep		5.93	5.92	5.93	0.00	10	45.88	45.17	46.77	0.56	10	0.00	0.00	0.00
	Oct		5.70	5.67	5.72	0.02	10	3.22	3.07	3.36	0.09	10	0.00	0.00	0.00

<sup>1</sup>To avoid conflicting with the June 1 – July 15 closure of upper Muir Inlet to motorized access, the “June” sampling date was actually May 31; hence data from May and June cruises are averaged together.



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